N73-27118

JSC-07985

APOLLO 17 MISSION

ANOMALY REPORT NO. 1

ERRONEOUS MEASUREMENTS TRANSMITTED BY TELEMETRY

National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas
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STATEMENT

Erroneous data were transmitted by 60 of the 1 sample-per-second telemetry channels for a 2-minute period beginning at about 191 hours 40 minutes.

SYSTEM DESCRIPTION

The telemetry system is of the pulse-code-modulation type and includes a programmer, an analog multiplexer, an analog-to-digital converter, a digital multiplexer, an output shift register, and associated power supplies (fig. 1).

The programmer provides primary control for the system which operates in either a high-bit-rate (51 200 bits per second) format or a low-bit-rate (1600 bits per second) format. The programmer supplies timing and control commands for all data-carrying components, including the commands which cause the analog multiplexer to sequentially sample the analog input channels.

The multiplexer is made up of five sub-multiplexers, each of which samples its assigned channels at a different rate. These sample rates are 1, 10, 50, 100, and 200 samples per second. Each sub-multiplexer is arranged as a logic matrix (fig. 2), wherein each measurement input is sequentially sampled by the simultaneous application of a row and a column command to the matrix. Each measurement input sample supplies a voltage pulse having an amplitude proportional to the measurement value, and this pulse is transmitted to the analog-to-digital converter. The pulse amplitude is encoded into a digital word which is transmitted to the digital multiplexer for interleaving into the data-bit stream by the output shift register.

The telemetry system operates on a one-second duty cycle, with each duty cycle composed of 50 prime frames, each of which contain 128 words. Words 52, 84, and 116 of each 128-word prime frame are assigned as 1 sample-per-second data locations. Therefore, in 50 prime frames (one duty cycle) there are 150 one-sample-per-second data locations, and these are interleaved into the data bit stream. The order of sequencing the 1 sample-per-second inputs is shown in figure 2.

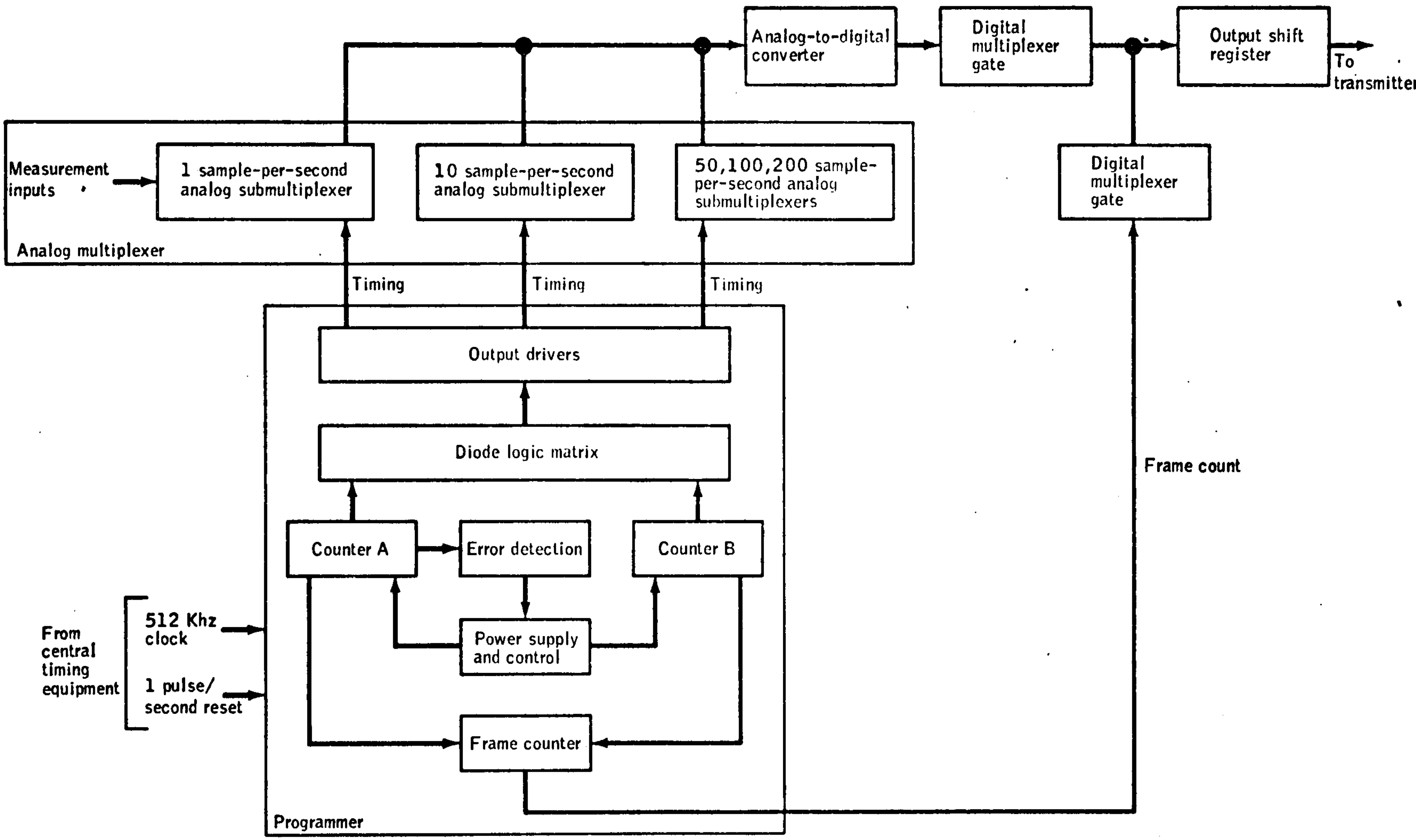

Figure 1. - Telemetry system analog measurement channels.

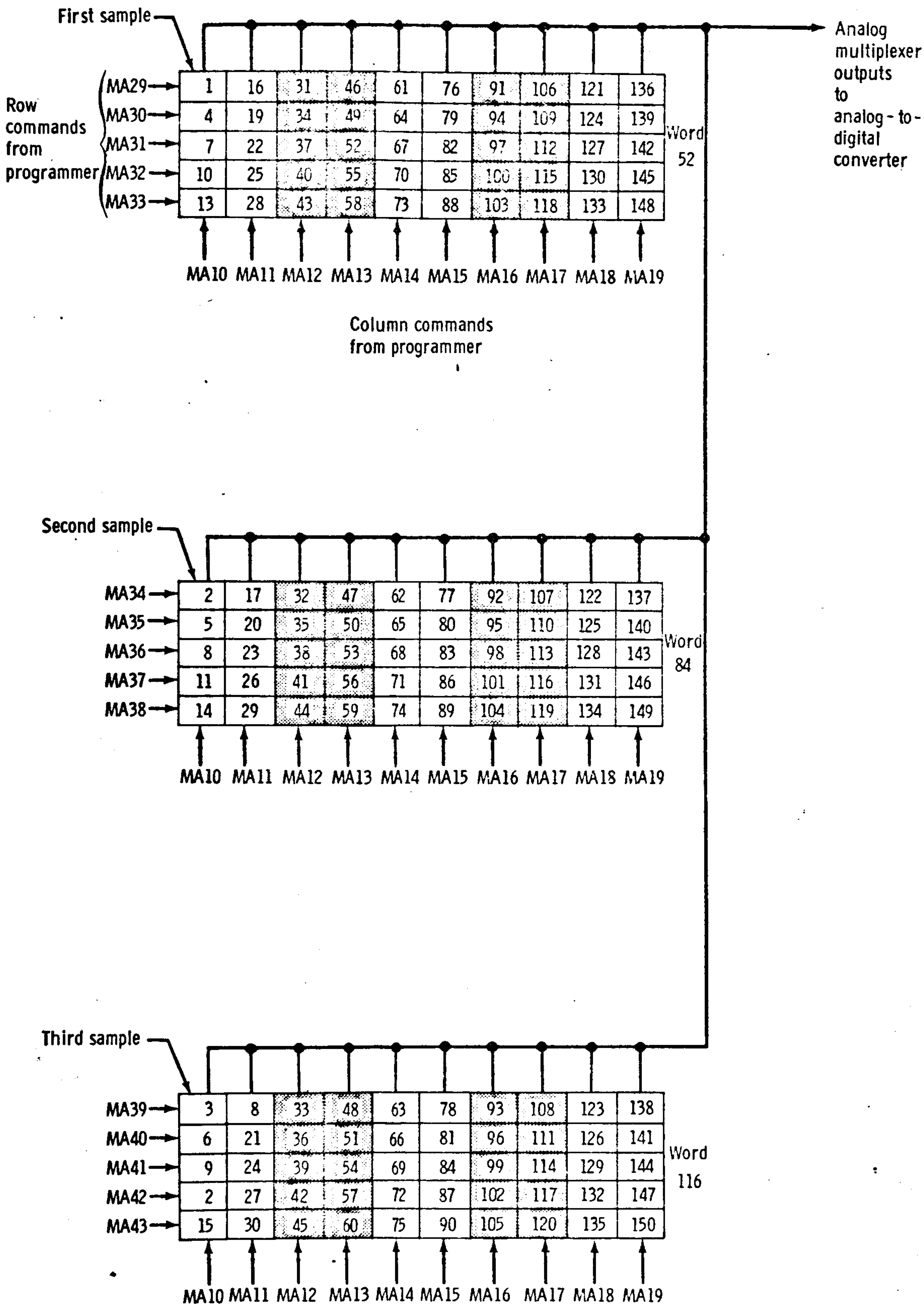

Figure 2. - Logic scheme of the one sample/second analog sub-multiplexer.

Programmer timing is provided by a 512-kHz signal from the spacecraft central timing equipment. If the central timing equipment signal is not present, the programmer will automatically switch to an internal timing oscillator.

The 512-kHz signal is counted down in one of two redundant programmer binary counters. The outputs from the various counter stages produce different time-based pulse trains that are supplied to diode logic where the programmer timing commands are generated. The counter is allowed to count for one second, then resets to zero, and starts counting again.

Both programmer counters (fig. 1) may provide identical pulse-train inputs to the diode logic. However, only one programmer is powered at any given time, and the de-energized programmer counter does not affect the logic.

The programmer counter supplies a pulse to increment the prime frame counter every 1/50 second (fig. 3). At the beginning of each prime frame, the frame count accumulated in the prime-frame counter is supplied to the digital multiplexer for interleaving in the data-bit stream. When the programmer counter is reset to zero, the last stage of the programmer counter resets the prime-frame counter to zero (fig. 3). The prime-frame count is used for synchronization purposes in the ground station data-reduction equipment.

The programmer power supply applies power to programmer-counter A when system power is applied. Operation of the last stage of counter A is monitored by failure detection circuitry (fig. 3) so that if the last stage of counter A switches in less time than 0.8 second (0.8 duty cycle) or does not switch during a duty cycle, power is removed from counter A and applied to counter B.

DATA

Erroneous readings were displayed by 60 of the 150 one-sample-per-second analog inputs for most of a 2-minute period starting at 191:40:39.485. Figure 4a shows the measurement values that existed just prior to the problem. The values range from a digital count of 1 to 254 representing an input signal range from zero to +5 volts. Improper readings were indicated on 4 of the 10 matrix column commands (MA 12, 13, 16, and 17) and on all 15 row commands (MA 29, through 43) as shown in figure 4b. Except for row commands MA 29, 34, and 39, the improper values were identical within ±1 bit for each row command line. The improper values were identical with individual inputs grounded, open-circuited, or connected to a measurement.

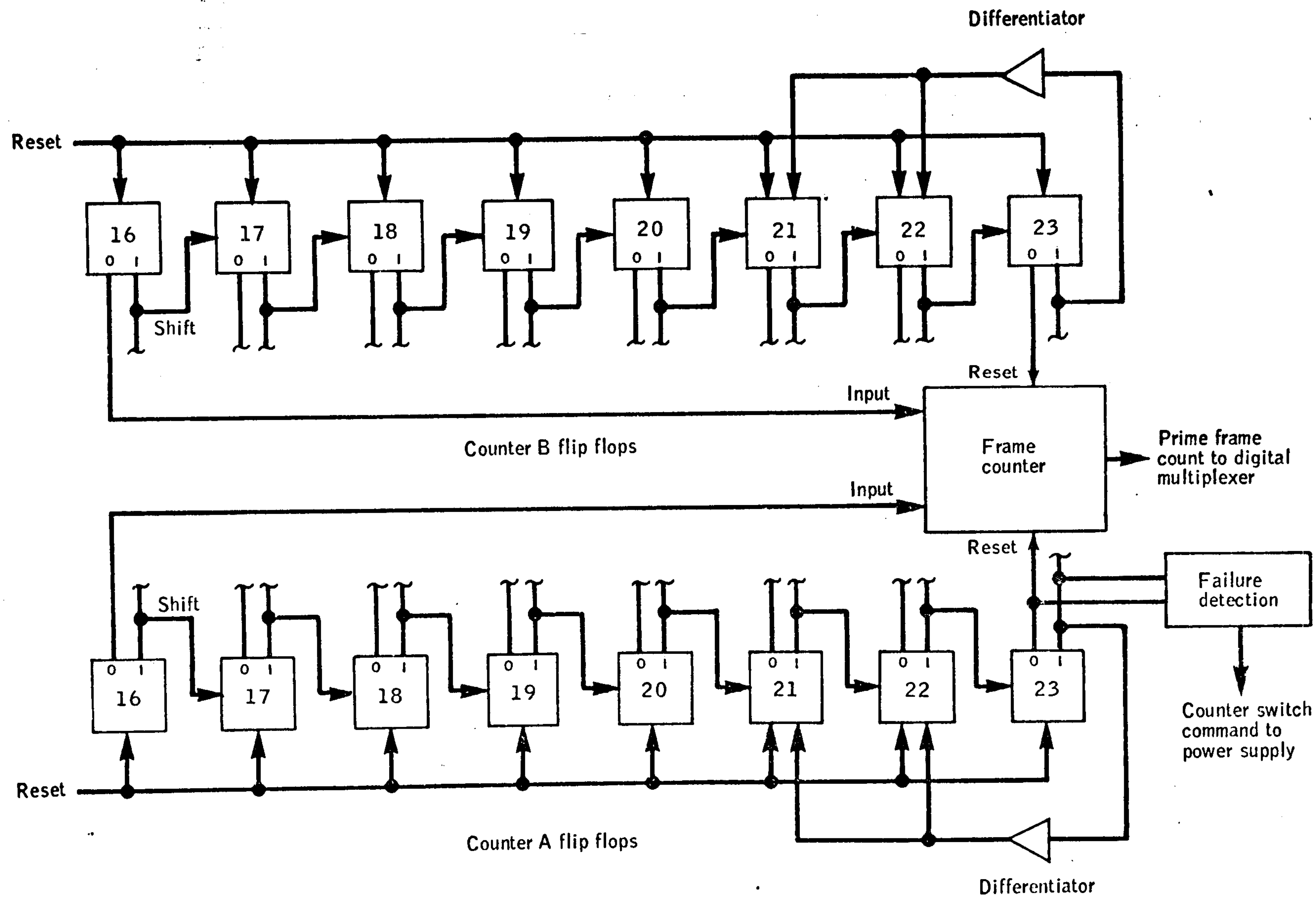

Figure 3.- Prime frame counter control.

Column commands

Row commands	MA10	MA11	MA12	MA13	MA14	MA15	MA16	MA17	MA18	MA19
MA29	35	144	1	1 g	152	1 g	233	1 g	1 g	132
MA30	254	124	1 g	42	1 g	61	1 g	1 g	1 g	122
MA31	1 g	254	106	1 g	139	254	19	1 g	1 g	123
MA32	113	1 g	1 o	1	55	223	103	1 g	133	2 o
MA33	1 g	1	1 g	3	1 g	101	1 g	1 g	183	1 g
MA34	116	117	1 g	132	147	1 g	1	1 g	1 g	124
MA35	115	117	1 g	1 g	51	1 g	1	1 g	1 g	110
MA36	254	96	1 g	1 g	1 g	167	1	1 g	113	2 o
MA37	115	1	1 o	1 g	1 g	105	132	1 g	136	1 g
MA38	1 g	1	93	92	60	68	1 g	1 g	1 g	239
MA39	95	205	168	124	16	193	173	36	35	8
MA40	79	205	164	35	218	247	1	36	119	134
MA41	133	166	174	104	40	110	158	254	119	141
MA42	184	166	160	103	191	1	168	17	123	151
MA43	187	171	164	15	189	127	170	1	35	214

(a) - Correct readings

Row commands	MA12	MA13	MA16	MA17
MA29	81	1 g	59	1 g
MA30	1 g	1	1 g	1 g
MA31	254	254 g	254	254 g
MA32	77 o	77	77	77 g
MA33	13 g	13	13 g	13 g
MA34	92 g	25	78	25 g
MA35	1 g	1 g	1	1 g
MA36	178 g	178 g	178	178 g
MA37	77 o	76 g	77	76 g
MA38	4	4	4 g	4 g
MA39	66	17	56	17
MA40	40	40	40	40
MA41	121	120	121	120
MA42	46	46	46	46
MA43	1	1	1	1

Note:
- g = grounded inputs
- o = open circuit inputs

(b) - Incorrect readings

Figure 4. - Data befor and during anomalous period.

Five subsidiary glitches occurred during the 2-minute period. The second and fifth of these had attendant frame count errors and the fifth had two gaps in the reduced data.

The first subsidiary glitch began 18 seconds into the problem and lasted until the next programmer-counter reset pulse zeroed all of the channels. During this glitch, all measurements during column commands MA 12 through MA 19 were improper. Values for MA 12 were identical to the MA 12 values given in figure 4b and values for MA 13 through 19 were identical with the MA 13 values given in figure 4b. After the programmer counter was reset, the improper data pattern shown in figure 4b returned.

The second subsidiary glitch started 23 seconds into the 2-minute problem period and again ended when the subsequent reset pulse was generated by the programmer counter.

The data for each of the ten column commands was as follows:

a. MA 10 - good data, same as figure 4a

b. MA 11 - good data, same as figure 4a

c. MA 12 - bad data, same as figure 4b

d. MA 13 - bad data, same as figure 4b

e. MA 14 - bad data, same as MA 13, figure 4b

f. MA 15 - bad data, same as MA 13, figure 4b

g. MA 16 - good data for MA 14, figure 4a (columns interchanged)

h. MA 17 - good data for MA 15, figure 4a (columns interchanged)

i. MA 18 - bad data for MA 16, figure 4b

j. MA 19 - bad data for MA 17, figure 4b.

In addition, the prime-frame counter reset to zero at the time it should have increased from 41 to 42. The data again returned to the figure 4b pattern after this subsidiary glitch cleared.

The third subsidiary glitch started 42 seconds into the problem and was identical to the second, except there were no frame-count errors.

The fourth subsidiary glitch began 110 seconds into the problem and differs from the preceding subsidiary glitches in that the problem appears to try to clear. The first three channels sampled in column MA 12 (that is, rows MA 29, 34, and 39) were identical to the values shown in figure 4b. The remainder of MA 12 and all of MA 13 were normal as shown in figure 4a. The columns MA 16 and 17 reverted back to the improper readings as shown in figure 4b. After the programmer counter was reset, the figure 4b data pattern again returned.

The last subsidiary glitch started at 113 seconds into the problem and lasted for about four seconds. The first two duty cycles (at 113 and 114 seconds) of data were identical to the improper data pattern shown in figure 4b except that MA 18 and 19 data were identical to the improper MA 17 values in figure 4b. Frame-count errors and gaps in reduced data occurred as shown in the following table. From the start of the 115th second to the end of the mission, the bad data as shown in figure 4b never recurred.

Time	Frame counter	Frame data
115 seconds	1	normal data
	2	normal data
	3	normal data
	40-millisecond gap in reduced data	
	1	frame 2 data
	2 to 45	frame 4 to 47 data
116 seconds	20-millisecond gap in reduced data	
	2 to 50	frame 2 to 50 data

The failure detection circuit must have commanded switchover to redundant counter B at the end of the 114th second of data. The switchover occurred during the 40-millisecond gap and the frame counter was reset to zero by removing power from counter A. At this time, the flip flops in counter B properly came on in states corresponding to frame 1. The ground station then locked up one frame later. The measurement sequencing then skipped from frame 2 (data) to frame 4 (data). The only way this could occur is for counter flip-flop 17 to receive an extra pulse. The spurious pulse could have resulted from the power-up transients that commonly occur at counter switchover.

At the end of the 115th second, which occurred at the end of frame count 45, the normal counter-reset pulse reset the programmer and frame counters. Since the frame count skipped from 45 to 1, the ground data reduction system lost synchronization for one prime frame of 20 milliseconds. Thereafter, no further problems occurred.

DISCUSSION

The telemetry system operated properly on both programmer counters during postflight testing, (the ground support equipment can select operation of either counter A or B.

The erroneous readings occurred during all 1-sample-per-second sub-multiplexer row commands and during only 4 of the 10 column commands. Since the row commands are also used in the 10-sample-per-second sub-multiplexer where operation was proper, the row commands must have been proper. The column commands, however, are used only in the 1-sample-per-second sub-multiplexer, consequently, the problem must have been caused by improper column commands.

The 10 column commands, MA 10 through 19 (fig. 5), are derived from 10 pairs of signal inputs. A common signal derived from counter flip-flops 10 through 19 is the first input of all ten pairs. Ten unique 5-frame group signals derived from counter flip-flops 20 through 23 are the second inputs to the 10 pairs. Commands using outputs derived from flip-flops 10 through 19 are also used to control other parts of the system which operated properly. Since flip-flops 20 through 23 are only used to generate column commands MA 10 through 19, the problem must have been confined to flip-flops 20 through 23, or their associated output circuits.

Figure 6 is a timing diagram for flip-flops 20 through 23 and the 5 frame group signals. At 0.8 second into the duty cycle, when flip-flop 23 transfers, the differentiator feed-back resets flip-flops 21 and 22 as shown in the timing diagram (fig. 6).

During most of the anomalous 2-minute period, the improper measurement values did not change. This could only occur if a hard failure, such as a shorted component or an open circuit existed for this period. The subsidiary changes or glitches that did occur could then have been caused by the fault becoming intermittent. Since some of the values in figure 4b do not correspond to any proper value in the same row of figure 4a, two or more of the column commands must have occurred simultaneously to cause erroneous values to be outputed from the 1-sample-per-second analog matrix.

The prime frame counter was reset after prime frame 41 (rather than after prime frame 50, indicating a reset at about 0.82 second) during the second subsidiary glitch. Since the prime-frame counter is reset by flip-flop 23, and the frame counter was reset after prime frame 41, flip-flop 23 must have switched at 0.82 second. Since flip-flops 20 through 23 should not be switching at 0.82 second (fig. 6b), the problem must have been in the last four stages of programmer counter A.

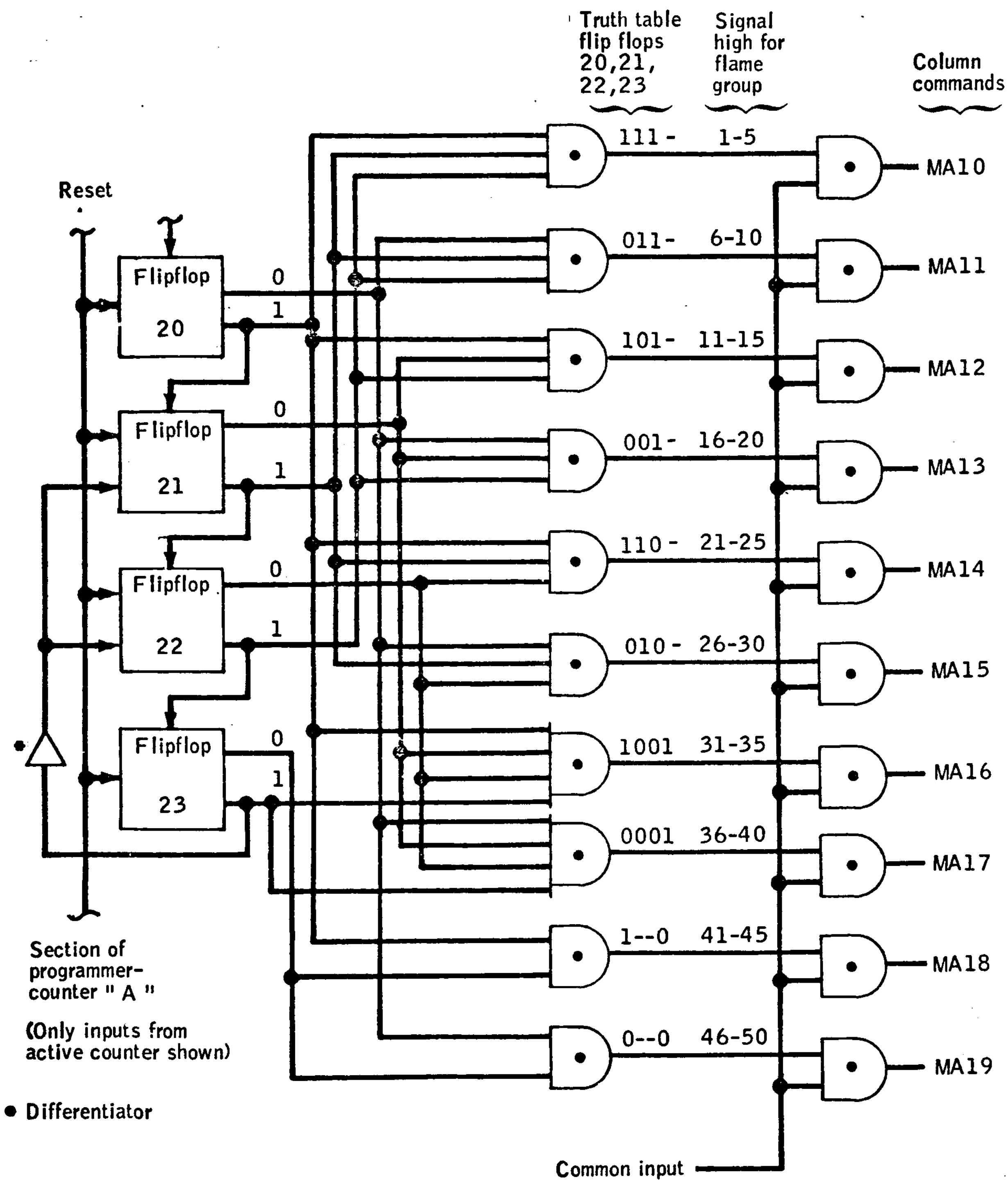

Figure 5.- One sample-per second column command generation.

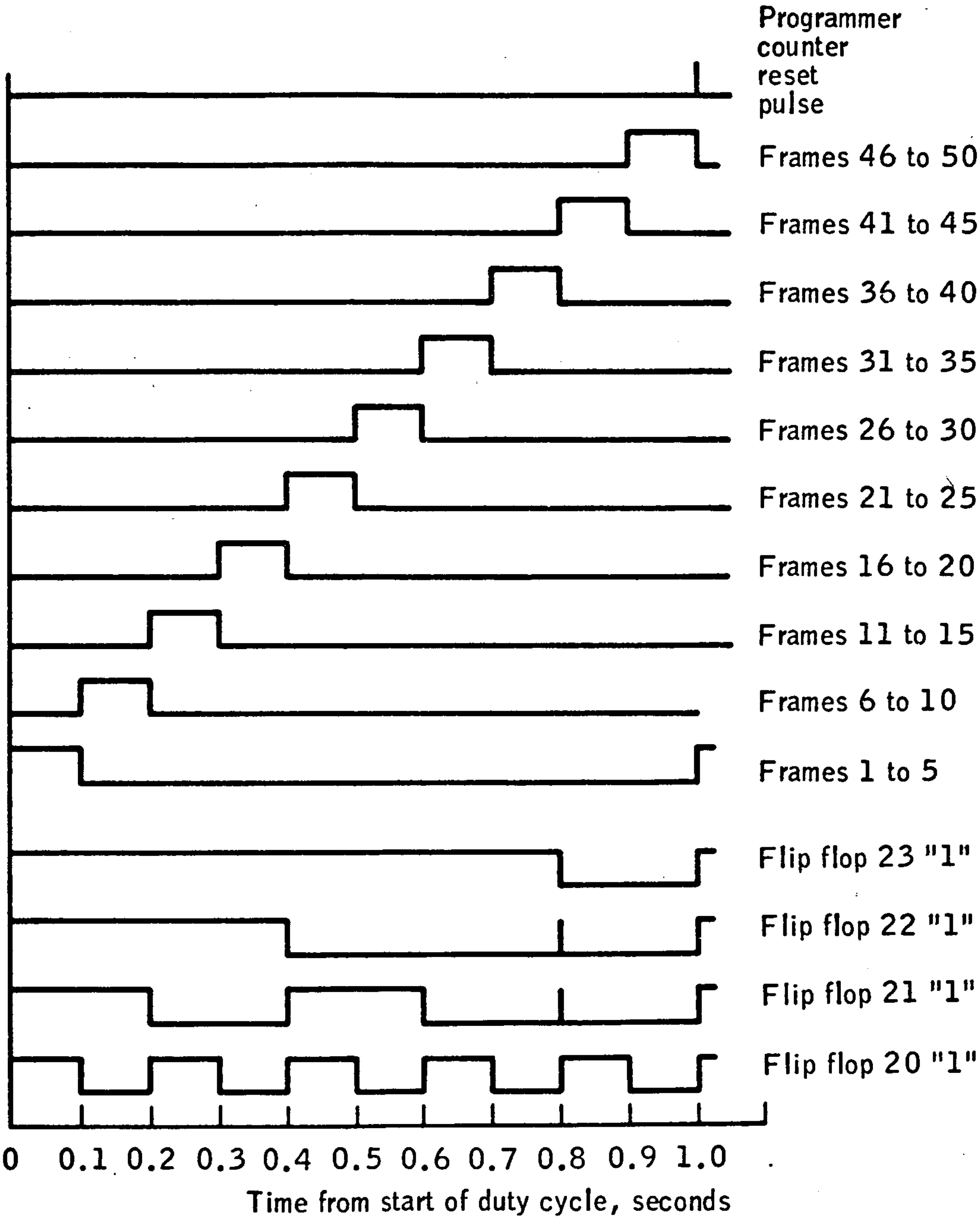

Figure 6. - Timing diagram for normal operation.

CONCLUSIONS

A failure occurred somewhere in the last four stages of programmer counter A. If the failure had not become intermittent, automatic counter switchover would not have occurred, and the affected measurements would have been permanently lost.

CORRECTIVE ACTION

A circuit is wired to a pin on the telemetry package ground support equipment interface connector which allows the ground support equipment to manually command programmer-counter switchover during ground test by grounding that pin. A mating connector will be carried in the Skylab and the Apollo Soyuz Test Program spacecraft. The connector will have an internal jumper that grounds the proper pin so that the crew can initiate the desired programmer counter switchover.